Barnes (H. J.)

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EPURATION OF SEWAGE BY IRRIGATION AND AGRICULTURE.

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[Reprinted from the Boston Medical and Surgical Journal of June 19 and 26, and July 24, 1884.]

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SEWERAGE SYSTEMS AND THE EPURATION OF SEWAGE BY IRRIGATION AND AGRICULTURE.[1]

BY HENRY J. BARNES, M. D.

MANY of the cities and towns of Massachusetts, as well as those throughout the country, have in the near future this question to dispose of in a scientific and practical manner. Political economy and the public health demand already in many communities attention to this subject. An epidemic of typhoid fever in a neighboring town would be a very dangerous menace to the health of the citizens of Boston in consequence of the water supply of the latter being the receptacle for the drainage and dejections of the inhabitants of the former. A beautiful lake in the vicinity of Boston is made so filthy by a large sewer discharging in it, that twice a public cry of reprobation has been raised against it. The valley of one of our large rivers has been rendered almost uninhabitable by the drainage of a large inland city. It is now said that the citizens of Chicago are much of the time drinking their own sewage as a result of taking water from a lake with which their sewerage system connects, and we may add that the city which is not troubled by its system of drainage is the exception and not the rule.

The effects of pollution by sewage of wells, springs, rivers, and ponds used for domestic purposes, are so generally recognized that no attempt is made to collate the many, many calamities which have befallen cities, towns, villages, and families through ignorance or indifference as to what disposition is made of the refuse matter of dwellings, and we must also acknowledge

[1] Read before the Section for Clinical Medicine, Pathology, and Hygiene of the Suffolk District Medical Society, April 30, 1884.

that a comprehensive system of disposing of sewage must be inaugurated in the near future, both in towns and by every individual hamlet. The present methods of gathering in cess-pools or subterranean channels, which discharge in a manner to jeopardize the health and comfort of ourselves and neighbors, must be abandoned for a system which shall dispose of and purify the sewage in a practical manner, or we must give up some of our large rivers for sewerage systems, or construct at enormous expense metropolitan systems, both of which have proved unsatisfactory or failures in Europe.

London's metropolitan system, which discharges in the maritime Thames about twenty-one miles below the city, of which so much was expected, and cited as an example Boston might imitate, has proved far from what was anticipated, The sewage instead of going to sea, or being diluted to an extent which would render it innoxious, is deposited by the tides above and below the mouth of the sewer in such a quantity as to cause a great cry of indignation from the inhabitants living along the banks of the river, and numerous petitions to Parliament asking for relief have been presented.

Torquay and Brighton draining directly into the sea have experienced similar results, and their systems are pronounced failures. The once beautiful bay of Naples is to-day a reeking pool of filth. A recitation of the many examples of pollution of rivers both in Europe and America, and the attendant evil, is unnecessary, but the following list of English cities where the courts have enjoined drainage in rivers suggest what we may anticipate in this country: Banbury, Blackburn, Chorley, Doncaster, Harrowgate, Leamington, Merthyr-Tydfil, Rugby, Tunbridge Wells, Warwick, Kendal, Birmingham, Bolton le Moor, Bradford, Coventry, Leeds, Halifax, and Rochdale.

In 1870 the Royal Commissioners reporting on the pollution of the Mersey and the Ribble stated that

"sewage discharged in running water is not materially changed for many hours by oxidation." This they demonstrated by the following experiment: A volume of filtered sewage from a drain of London was mixed with nine parts of pure water. Analysis of this mixture showed it to contain per 100,000 parts 267 parts of carbonaceous matter and .81 parts of nitrogenous matter. It was exposed each day to light and air, shaken and drawn by small siphons in a manner to cause a fall of over three feet from vessel to vessel. At the end of 96 hours there remained 250 parts of carbonaceous matter and .58 parts of nitrogenous matter, indicating a loss of but 17 parts of carbonaceous matter and .23 parts of nitrogenous matter. At the end of 192 hours it had lost but 25 per cent. of carbonaceous matter and $33\frac{1}{3}$ per cent. of nitrogenous matter. This experiment was made in a temperature of about 68° F., and designed to show the change likely to take place in the current of a river running at the rate of one mile per hour, and carrying ten per cent. of sewage. They concluded there was not a river in England long enough to dispose of a moderate amount of sewage through oxidation.

J. Babut du Maris says, it has been proved that the waters of rivers do not lose a material amount of azote in a run of over three hundred miles. And the Prussian Government has consequently forbidden the pollution of rivers and sea-ports by the discharge of detritus of the cities.

The effects of imperfect sewerage systems are forcibly portrayed in a paper printed in the *Boston Medical and Surgical Journal* of February 22 and March 1, 1883. In that paper Dr. Morton Prince collates many epidemics of typhoid fever from this cause. He says, "It is estimated that in this State (Massachusetts) alone there are ten thousand cases of typhoid each year," and every one knows a large proportion may be fairly charged to defective drainage. How imperfect sewerage causes this disease was well illustrated at Na-

hant, Massachusetts, in 1881, and thoroughly reported by Mr. Ernest Bowditch. A paragraph from page 246 of the Supplementary Report of the State Board of Health, 1882–83, would properly introduce the question discussed in this paper, as the successful epuration of sewage by irrigation and agriculture depends upon where, and to what extent, nature provides in the soil for the elimination of filth. Mr. Bowditch says, after noting the improvement in the sanitary condition of the town the year following the epidemic, "While the conclusions, as to soil recovery, may be derived from insufficient premises, perhaps calling attention to the subject may lead to the discovery of facts warranting systematic research in this direction that may be of great sanitary value." Dr. Frankland wrote in May, 1881: "There are in nature powerful agents for the destruction of disease. It cannot be doubted, otherwise the human race would long ago have been exterminated. The problem is not entirely solved, but experience appears to demonstrate this action on sewage employed in irrigation; for when known to be infected by cholera and typhoid fever in England it has never produced these diseases in the inhabitants living on the sewage farms and consuming the produce."

Many and varied are the systems adopted and methods employed with the object of disposing of sewage. Surface drainage, cess-pools, subterranean drainage, and the pneumatic system of Liemur are employed for collecting and discharging in rivers, ponds, bays, oceans, and on the land are the most common means of distribution. Filtration, precipitation, the employment of chemical agents, irrigation, and agriculture are some of the measures adopted for the purpose of epuration.

CESS-POOLS.

Depositing sewage in cess-pools is one of the most common as well as antiquated methods employed. They are emptied at intervals varying from one week to five or more years. They involve the concentration of fer-

mentescible matter and the consequent generation of gases dangerous to health, beside the vitiation of subsoil water. The soluble organic matter contained in them is capable of very long journeys under ground, with the loss of coloring matter only, as many analyses have proved. Their use should not be tolerated, except the walls are made impervious to liquids, and their being emptied at short intervals. A writer on the subject says: "The time is not far distant when they will be pronounced a relic of barbarism."

DOWNWARD INTERMITTENT FILTRATION PRACTICED AT KENDAL, ENGLAND.

The population is about 14,000. There are 450 water closets connected with the sewers, which discharge 868,000 gallons per day. A reservoir of deposit was first constructed, which overflowed on a farm of about fifteen acres, with the object of utilization by agriculture. The area of the farm proved insufficient to epurate the sewage completely, and five acres of filter beds were added. These, with the farm, suffice to purify the water. In 1875 the products of one third of the farm, consisting of cabbages, beets, celery, and rhubarb, sold for $500. Oats and rye on another third $375, and on the remaining five acres $225 worth of hay was raised, making a total of $1100 worth of produce from fifteen acres. The application of the sewage cost $550.

The operation of the same system constructed by I. Bailey Denton at Abingdon, Great Malvern, and Halstead, England, and at Forfar, Scotland, has proved satisfactory, inasmuch as sufficient matter is eliminated to allow the effluent discharge into neighboring rivers, although it contains a large amount of putrescible matter, as indicated by analyses. It just escapes the ban of the Pollution Act.

THE PNEUMATIC SYSTEM OF LIEMUR

is employed at Amsterdam for a limited number of the inhabitants. The sewer pipes are made of iron, with

air-tight joints. An air-pump makes a vacuum. Closets are opened simultaneously once a day in section after section of the city; the contents are drawn to the mouth of the sewer, from which they are carried away in barrels and deposited on the land. Its enormous cost bars its employment where any other system can be used.

UPWARD FILTRATION AT BIRMINGHAM, ENGLAND.

Population about 350,000. Eight thousand water closets are connected with the sewers, which discharge about 14,000,000 gallons per day in the river Tame. An injunction was obtained to prevent the discharge in the river unless the sewage was first purified. A reservoir of deposit was built, and a system of upward filtration, but complaint of the continued pollution of the river necessitated its abandonment. The city then attempted irrigation and agriculture, but this was also enjoined. Finally, after much delay and litigation, the city bought 120 acres of land, and on the advice of an engineer constructed a new reservoir of deposit, where they treat the sewage with lime. To 13,434,860 gallons is added thirteen tons of lime each day. This clarifies the water to a certain extent by causing a deposit of about 300 tons per day, which is carted out and buried on the land.

It has been an easy matter to separate material in suspension from drain water by filtration, but as this represents only about one seventh part of the value of sewage for fertilizing purposes, the process, though simple, has never proved remunerative, and chemists have been employed to suggest agents which would precipitate the soluble matter, which represents six sevenths of the value. Lime has been employed at Tottenham, Blackburn, and Leicester, but the Royal Commissioners report of each a failure, inasmuch as the drain water after being thus treated contains a large amount of putrescible matter.

TREATMENT BY LIME AND CHLORIDE OF IRON AT NORTHAMPTON, ENGLAND.

To 250,000 gallons of sewage is added about 100 quarts of lime and six quarts of chloride of iron, which is thoroughly mixed, and afterwards passed by upward filtration through a layer of calcinated iron eight inches thick. The water comes out without color or odor, and is then allowed to flow into the river. At first there was no complaint, notwithstanding the presence of a large amount of putrescible matter, but later the river became offensive, and the court enjoined the discharge there.

THE A. B. C. METHOD OF SILLAR.

A mixture consisting of six hundred parts of alum, twenty-five parts of burned clay, one part of blood, ten parts of salt, nineteen hundred parts of clay, fifteen parts of animal charcoal, five parts of magnesia, twenty parts of wood charcoal, ten parts of manganate of potash, two parts of calcined magnesia, is added to the sewage, to be treated in a proportion of about one pound of the mixture to 250 gallons, thoroughly agitated, and then allowed to settle in large reservoirs, which are alternately emptied, and the detritus taken out dried, and sold as a valuable fertilizer. The residuary water still contains putrescible matter, and notably more ammonia than the sewage before being treated.

PRECIPITATION BY CHEMICAL MEANS AT COVENTRY, ENGLAND.

Population 40,000. Five thousand water closets are connected with the sewers, which discharged 2,289,000 gallons of sewage in the river Sherburne. Complaint and litigation was the result. A reservoir of deposit was constructed, after which the sewage was allowed to filter across a gravel bed three feet thick. This proved unsatisfactory, as only solid matter was taken out, and

the court again interfered with an injunction. A contract was then made with a fertilizer company, which agreed to epurate the sewage for fourteen years at $3750 per year, the company engaging to erect building and machinery, and furnish the necessary tools. An extractor first separates the solid matter. The liquid is then run into caldrons under the first group of buildings. Agitators mix impure sulphate of alumine with it at a boiling temperature. It is then run into a second set of vessels, where milk of lime is added and thoroughly mixed, then discharged alternately into four reservoirs in the open air, which are cleaned every fourth day. The liquid thus treated comes out sufficiently pure, and is allowed to filter over about four acres, and finally find its way into the river. Thirty tons of detritus is taken each day from the reservoirs, piled to dry, and subsequently treated by artificial heat. The works are not in operation at night, except the discharge of sewage on the filter beds. Twenty-two tons of coal, one ton of sulphuric acid, nine tons of sulphate of alumine, and four tons of lime are used each week. The company's net loss is about $7500 each year.

After long and costly experiments the greatest chemists have declared that in practice the only manner to epurate sewage is to send it on the land, which eliminates the polluting elements and fertilizing matter for the good of vegetation and the soil. Dr. Angus Smith says: "In all cases the best results are obtained by irrigation." And Dr. Carpenter certifies, in a notice read at the International Congress in 1881, "the only way ammonia could be eliminated from sewage is by irrigation."

A commission appointed by Parliament, composed of Messrs. Dennison, Frankland, and Morton, reported: "The actual resources of chemistry do not permit the hope that the polluting matter dissolved in sewage can be precipitated and sent away by any appliance of chemical reaction, and unless new chemical laws are

discovered it is useless to attempt the employment of chemical agents. Epuration must be confided to Dame Nature."

"Millions of dollars have been expended in France in chemical experiments on sewage, all of which have been condemned." *J. Babut du Maris.*

At the Women's Prison in Sherborn, Massachusetts, epuration of sewage is attempted by what is known as Colonel Waring's method. Five acres of land are here employed in the water-shed of Lake Cochituate, about two miles from the lake, with which it is connected by a brook, one of the tributaries of Boston's water supply. The sewage is distributed over the land by tile with broken joints laid fourteen inches below the surface, five feet apart. The effluent drainage is provided for by cross sections of tile laid five feet under ground, which, after collecting the water, discharge in the brook. This system is said by the prison authorities to work satisfactorily. "The water coming from the ground is as clear as spring water, and was selected by an expert as such on inspection." This only indicates clarification, and we regret that analyses made were not published, as no one seems to know where they are at the present time. There can be no doubt but the grass, which is the vegetation on the land, takes nourishment from the sewage, for the lines of drain are clearly marked by a better growth directly over them which does not extend to the intervals between. One of the defects of this system has already been experienced. Insoluble matter has filled the interstices between the tile, and prevented fluids from passing through, necessitating their being taken up and relaid. At a depth of fourteen inches the influence of vegetation and the infusoria must be lost on much of the sewage, which was probably disclosed by the analyses, rendering it desirable they should be pigeon-holed. Since writing the preceding, a visit to the prison more than confirms the anticipated objection to the system, and the following analyses, obtained in the office of the

State Board of Health, are proof beyond dispute that the system amounts to nothing by way of purifying the sewage; and that the system is practically a mammoth cess-pool, the contents of which the citizens of Boston must drink: —

WOMEN'S PRISON SYSTEM. PARTS PER 100,000.

	Ammo.	Alb. Ammo.	Chlo.	Residue.
Supply End.	.240	.018	9.58	68.5
Flow End.	.232	.034	9.22	69.0

The exclusion of air from the sewage of this system keeps it fresh, the nitrogen is in an organic state, and consequently of no use to vegetation. A fertilizer should become ammoniacal by decomposition before it is capable of assimilation by plants. Analyses of sewage in Europe reveal the fact that there is no loss of fertilizing material in a closed conduit having a run of seven and one half miles. And examinations of the soil of sewage farms show that in all instances the sand one foot below the surface is as pure and white as that where irrigation is not practiced.

In the Mystic Valley the sewage of tanneries has for several years been pumped by the city of Boston into small reservoirs of deposit obviously too small to eliminate even the matter in suspension. From the tank there is an overflow into a shallow ditch several hundred feet long, in which are set several brush dams, after which it discharges into Mystic lower basin. The result of this treatment is to start putrefaction by warmth and free exposure to air, and thus produce a stench which people living in the vicinity claim has greatly reduced the value of real estate. It does not merit extended description, as the efforts thus far made merely amount to a flirtation with the subject.

A few of the farmers living along the Blackstone River are beginning to appreciate the valuable fertiliz-

ing material conveyed by the current from Worcester, Mass. One farmer states that his meadow lands, which were practically abandoned, it not paying to harvest the grass, now produce crops which add several hundred dollars a year to the value of his farm. Others are placing obstructions in the river with the object of turning the water on the land.

During the past ten years sanitarians and engineers have made great progress towards a solution of this question, and it is fair to presume, from the great increase in the number of cities and towns that have adopted irrigation and agriculture as the means of purifying sewage, that this method has proved the most satisfactory. Berlin has two large farms devoted to this object, one of 2035 acres and another of 1818 acres. A great many chemical experiments were tried before the adoption of the present system. They proved very expensive, and none purified the water, although many clarified it. Finally, after experimenting in irrigation and agriculture for eighteen months on a little field of about three hectares (less than seven and one half acres), such favorable results were realized that this system was adopted for the city, — the eminent Virchow working heartily in its favor. At the present time 1067 acres suffice to purify 15,060,000 gallons per day, the drainage of four fifths of the city, containing a population of over 600,000. There is some odor at the opening of the large sewer, but in the fields there is no smell and the sanitary condition is all that could be desired. There never has been any complaint from the numerous adjoining habitations, and the effluent drain water of the farms is pure and clear, it being impossible to recognize by microscopy or chemistry any influences of the sewage. Vegetables and fruit trees grow luxuriantly on the land, and their roots make a perfect filter. Thirteen and one quarter tons of hay has been cut per hectare (a little less than two and one half acres).

Dantzic, situated about three miles from the Baltic,

on account of pollution of its harbor at the mouth of the Vistula, constructed a sewer to discharge on a sandy island having little or no soil, where the occasional tufts of grass were frequently covered with sand carried by the wind. As a result the island is now in a high state of cultivation. In some parts the land rents to peasants at from twenty to thirty dollars per acre. The frosts of winter do not interfere with the successful operation, as the water delivered by the sewer melts the snow and ice, so that it finds its way into the ground quite as well as in summer, and without injury to the slumbering vegetation. Odessa, Breslau, and Florence also have sewage farms. M. A. Durand-Claye, from whose reports this information is derived, says that "in Germany it is admitted without question that municipal healthfulness depends upon three principles: first, the total discharge of water-closets in sewers; second, the distribution of an abundant supply of water in dwellings, and frequent flushing of drains; third, the purification of sewage by soil and vegetation."

In England there are two hundred cities and towns disposing of sewage by irrigation and agriculture. On the farms at Edinburgh are located beautiful nurseries for the children of the city. At Lochend a farm taking sewage from this city has produced $200 worth of hay per acre. The Metropolitan Sewer Company of London rents land at $100 per acre for grazing. Sixteen acres at Rugby furnish feed for fifty-four head of cattle, and at Aldershot, Branbury, Bedford, Croydon, Norwood, Warwick, and Worthing the reports in detail show an equally wonderful production from the land treated in this manner.

Leamington, with 26,000 inhabitants, spent $40,000 in chemical experiments, after which the A. B. C. Company in 1869 attempted to purify the sewage, but gave it up in 1871. It was then allowed to flow into the River Leam. A lawsuit followed, costing the city $25,000, in which it was defeated, and compelled at

an expense of $7500 more to purify the river. Lord Warwick then consented to receive the sewage on his estate, the city contracting to deliver it at the highest point of the farm for a period of thirty-two years, for which Lord Warwick engages to pay $2250 annually. The sewage amounts to a little over 1,000,000 gallons per day, and is distributed over the land, which has not been leveled, by what is known as the "donkey back" system, — elevated open drains, on the sides of which is the vegetation. It has transformed the poorest parts of the farm into soil of much fertility, and financially has proved a great success. From eight to nine cuts of Italian rye grass two feet high are made each year. Celery, strawberries, and currants grow remarkably well. The beef, milk, and butter are in great demand and bring the highest prices. The laborers are in the best of health, and Lord Warwick has received numerous prizes and silver cups for one of the best kept farms in the kingdom. A more detailed account may be found in Babut du Maris' work.

The sewage farm at Croydon is surrounded by beautiful villas, it being a fashionable resort. The land which twenty years ago sold for $300 per acre is now worth from $2,000 to $5,000. There has been but one complaint of the farm during the past twelve years, and this resulted from excessive irrigation during a long period of stormy weather, when the hay could not be dried on the land.

A public footpath crosses the sewage farm at Abingdon. There has been no complaint from bad odor.

Babut du Maris says, "It has been claimed that prolonged irrigation will produce disease by the presence of bacteria in the sewage. Experience is to the contrary. The farms at Edinburgh have received sewage for more than two centuries, that at Buntzlau for two and a half centuries, and for more than ten centuries this has been in practice in China. Vegetation has never ceased to be vigorous and healthy, and the inhabitants have never been known to suffer in consequence of irrigation."

I am informed by a gentleman who has resided seven or eight years in China that in all the large cities the detritus is carried into the suburbs by hand buckets and deposited on the land for the benefit of vegetation, and in many instances the same pails serve to bring back drinking water, with no ill effect except in a few northern cities, where the sewage is put on the leaves of vegetation; there the tape-worm is very common. Dr. Williams, in his work entitled "The Middle Kingdom," does not include typhus, typhoid, scarlet fever, or diphtheria in a list of the prevalent diseases of China.

It is difficult to make comparisons or draw conclusions when considering this question financially, for the paramount objects to be attained vary in different communities. One town may seek only to get rid of the sewage, another its most profitable employment on the land, another relief from the pollution of a water-course or preservation of its navigability; grotesque and unprofitable experiments and local conditions all contributing to make balance sheets of great diversity in showing either profit or loss. Many examples of each are available, and should of course be carefully studied.

The city of Paris, for many years harassed by constant complaint and litigation as a result of discharging sewage in the Seine, some years since established sewage farms on the plains of Gennevilliers, the history of which is told in a report to the municipal council by the sixth Commission appointed to treat with the state for the concession of such public lands at Achères as are necessary for the epuration of the sewage by irrigation and agriculture.

Before the execution of the measures conceived by M. Belgrand for the general healthfulness of Paris, the rain water and the washings of the streets flowed into the Seine, either directly, or by a great number of drains emptying on the quays of each bank the whole length of Paris. This mode of drainage resulted in the immediate and pronounced pollution of the river, which reached the maximum at the point where it

leaves the city. The work of Belgrand had for its result the concentration of four fifths of the drain water in a large sewer opening into the river at Clichy while the remainder was discharged at St. Denis. At the same time the water for domestic supply was largely increased. In 1860 50,000,000 gallons per day were furnished for this purpose; in 1882 92,000,000 gallons were required each day, or 34,020,000,000 gallons per year. This, with the rain water which falls on the city, estimated at from 9,576,000,000 to 11,340,000,000 gallons, makes a total of 44,100,000,000 to 45,360,000,000 gallons, which, were it not for evaporation and other loss, should be carried by the sewers. This loss amounts to something like 18,900,000,000 gallons per year as indicated by gauges in the two sewers, which register 26,208,000,000 gallons (about 42 per cent. disappearing by evaporation). At low water of the Seine it is equal to one part of drain water to twenty of river water, and at high water to one part in 350. As a result of currents and obstacles in the river, mixing did not take place; and the right bank — the most densely peopled — received on a very long margin the totality of the drain water, depositing all the way organic matter brought in suspension. Protestations from people living along the right bank of the river followed very closely the opening of the two great sewers; and the state government required the city of Paris to seriously consider methods of purifying the sewage before discharging it into the river. The savants, engineers, chemists, traders, and agriculturists discussed the subject in all its phases, and to the latter we are indebted for a practical solution of the problem.

Filtrage was naturally the first system to be tried. It was soon found that, besides the actual difficulties of filtration on so large a scale, this mode of treatment had the capital vice of leaving in the water soluble organic matter capable of fermentation, and later, chemical agents were resorted to with the object of precipi-

tating the soluble matter, but only incomplete results were obtained, which were slow, costly, and inapplicable on so large a scale.

We now come to the experiment which after fifteen years of study and persevering effort has given a result most complete and satisfactory. Epuration and utilization by agriculture, and filtration by spreading the sewage on permeable land, have accomplished this end. It is based on simple principles, of which the demonstration is now made. All argilo-silicious and permeable soils, sufficiently thick and well drained, have the property of retaining in their superior layers all the organic matter in suspension and solution contained in drain water spread on the surface of the land. Such soil can receive without being made damp or marshy one inch of water per day, or twenty-six feet per year. It transforms the retained organic matter, rendering it capable of assimilation by plants. A very ingenious experiment lately made shows this valuable property in the vegetable mould. A hollow column two metres in height was filled with earth in a manner to reproduce exactly the soil as found at Gennevilliers. Through this was passed sewage in a relative quantity to that employed in irrigation and at equal intervals with its use on the land. Epuration took place as completely as in the natural earth. Chloroform was then passed through the column, which at once arrested epuration, and the sewage traversed the column without being purified. Paralyzation of the infusoria stopped oxidation of the organic matter. This experiment has been demonstrated by M. Schloessing, and is described in the report to the Council of Hygiene. If the surface irrigated is under cultivation the fertilizing matter is immediately utilized; if not, it accumulates without loss and transforms the poorest soil into land of extreme fertility.

A very large proportion of the water used in irrigation is evaporated either directly or by the plants in vegetation. The residuary water coming from the

subsoil drains is of a remarkable purity, and does not suggest either by aspect or composition the sewage from which it proceeds. Irrigation is the most economical and efficacious means of conveying directly to the plants the fertilizing matter of sewage.

Trusting in these principles, and fortified by the works of Messrs. De Freycinet, Schloessing, Marié-Davy, and Frankland, the engineers of the municipal service have, since 1867, pursued studies and made experiments for which, notably since 1872, the council has furnished a large amount of money. These efforts have had as a result the great and actual demonstration at Gennevilliers, which evidence impresses favorably all unprejudiced persons who take the trouble to visit the lands.

After some experimental cultivation at Clichy in 1867 and 1868 the irrigation of the plains of Gennevilliers was begun in 1869 by Messrs. Mille and Durand-Claye. In 1870 and 1872 the territory comprised but a few hectares. It has increased each year, until now over 500 hectares are thus employed (about 1200 acres, which receive nearly one fourth the sewage of the city). In the beginning the water distributed was limited to a few thousand cubic metres. In 1872 144,000,000 gallons were used. In 1881 4,685,000,000 gallons were discharged on the land. In May of this year (1881) 684,300,000 gallons — 22,050,000 gallons per day, or 44,100 gallons per hectare per day — these plains absorbed. In 1882, at the time of the report, the distribution reached 34,020,000 gallons per day, or 79,300 gallons per hectare, which represents a sheet of water spread over the surface equal to a little over one inch per day.

The progress, the slowness of which astonishes us now, has not been obtained without difficulty. At the origin, the engineers, relying too much on the very great permeability of the land, had not thought it necessary to establish subsoil drainage. The natural drainage, in consequence of an abundant irrigation, was

found insufficient. The level of the subsoil water rose; a few cellars were flooded at Gennevilliers, and gravel quarries were inundated. This was sufficient excuse for claims for excessive damages against so rich a victim as the city of Paris. To increase the indemnity and to compel a compromise, all possible arguments were employed. Doctor was opposed to doctor, and hygienist to statistician, when it was only a question of a few thousand francs damage to the claimants. These demands were opposed by the engineers, who in turn were very decidedly sustained and supplied with money by the municipal council. The necessary work to insure the drainage of the plains and to remove all pretext for damages was done, and to-day the complaint is rather of the lowering of the subsoil water. Nevertheless irrigation at Gennevilliers created a prosperity until then unknown, and a time arrived when the community, frightened by the possible result of its demands and outcries, — which threatened to be the suppression of irrigation, — asked for a contract, the principal article of which was that the city should engage to continue irrigation on the plains of Gennevilliers for twelve years.

The efficacy of this system of epuration is manifest, and presents a brilliant proof. The effluent drain water has fewer micro-organisms than the water of the Seine when it enters Paris. It has the purity of spring water coming from the earth. To demonstrate the utility of the system as applied to agriculture has been slow and difficult, and not less laborious than to test the efficacy of the epuration.

The slowness of experiments in agriculture may be understood when we remember that to reach an end we must go through all the phases of vegetation, from the sowing of the seed to the harvest. Under our climate it is a campaign of a year. If we neglect a detail, if we make a mistake at the time of sowing or planting, at the time of plowing or watering, the harvest may be a failure, and we must begin again. The

difficulty was increased by local circumstances. Amongst the cultivators of land in the suburbs of Paris, no one knew the practical working of a sewage farm. One of the persistent workers who has been rewarded by success said recently that it required more than four years to acquire the necessary knowledge. To-day the cultivators are in complete possession of their art, and in the recent horticultural exhibition every one admired the remarkable products, which received honorable distinctions.

In agriculture, successes which would be shown by beautiful samples obtained in the fields of experiment would be objects of curiosity. It is necessary to secure economical results, and these go far beyond the utmost expectations. For the landlord of the soil the rent value of the hectare has increased fivefold, from 90 to 450 francs. For the farmer or cultivator the prosperity has not been less. The net value of vegetable products rose from little or nothing to 4000 francs per hectare.

In a sanitary point of view the results have not been less satisfactory, and here again it is necessary to observe the facts on the ground. One sees a numerous population, robust and healthy in proportion to its prosperity. Its vigor assures a healthy nutrition equivalent to its works, which is the best hygiene.

As to the effects of irrigation, the same occurs at Gennevilliers which always takes place where irrigation is practiced: from the moment it is made frequent, without stagnation, and at regular intervals, a condition which is far from favorable for the development of paludal influences. The determining causes are eliminated; a constant activity is maintained in the vegetable life, which absorbs in its circulation all its own residues and all the organic elements placed within reach. Highly to the honor of the city of Paris be it said that, by the perseverance of its representatives, by the science and devotion of its engineers, the problem of epuration of the residues of cities and of their utiliza-

tion by agriculture is absolutely and definitely solved. We have no longer the experiment of Gennevilliers; we have a system permanent and regular for the future.

The population of Gennevilliers has increased by farmers coming to occupy the lands thirty-four per cent. in ten years.

Among the city documents of Paris lately presented to the city of Boston, and placed in the Public Library, may be seen photographs of the departments of this branch of the municipal service, as well as of the products of the land. The commission, in recommending the acceptance by the city of the terms which the state proposes for the extension of the work so as to include the sewage of the entire city, recommends a municipal ordinance which shall require all the water-closets in the city to be connected with the drains, and an absolute abandonment of cess-pools, which now are so common in Paris. Up to the present time the city has declined to accede to the terms of the state, as they are deemed too exacting, and require a very large amount of money for the purchase of the land. The success of epuration by this method is not questioned. The work of Babut du Maris, lately published, says "the city has just obtained 2500 acres for the extension of the sewage farm."

The highly satisfactory operation of this system at Dantzic, where the rigorous climate of winter is as great an obstacle to overcome as here in Massachusetts, is sufficient proof that frost is not an objection to its employment on our soil. The land freezes four feet deep at Dantzic. The Vistula is frozen over from the middle of November to March, yet the temperature of the sewage at the mouth of the sewer never goes below 37° F. Irrigation is continued throughout the year with quite as much success in epuration in winter as in summer, although vegetation flourishes but four out of the twelve months.

Sewage in freezing, says Babut du Maris, eliminates its dissolved fertilizing material as thoroughly as salt water eliminates salt by the same process.

There must be abundance of land in the valley of the Blackstone, the Merrimac, and the Connecticut suitable for farms of this character. There is land bordering on Lake Cochituate well adapted to farming, for the protection of the lake from the sewage of Pegan Brook. In Arlington, Belmont, and Medford are vegetable farms favorably located, and soil well suited to this system: and before this community embarks in a scheme to build a metropolitan sewer from Natick to tide-water, which when finished will be of doubtful utility, judging from the experience of London, this system should be tested, with the object of requiring each and every community to take care of its own sewage.

We have in the soil a chemical laboratory, a perfect filter, oxidation, vegetation, the influences of animal life and the infusoria combining to protect the subsoil water, and so far as experience goes or chemical analyses can demonstrate, these processes of nature are amply sufficient.

We do not hesitate to cover with fertilizing material fields in which are located springs and wells. We are only solicitous lest the surface water should convey the material to them, and we raise an embankment above the level of the surrounding land, and otherwise leave to nature the protection of our drinking water with full confidence in "*vis conservatrix naturæ*," and if her processes are not complete and perfect the whole world is gradually becoming saturated with filth.

The paper was listened to by an audience composed of physicians and a large number of sanitarians and sanitary engineers, as well as a number of delegates from the Sanitary Boards of towns about Boston, the superintendent and physician of the Woman's Prison at Sherborn, representatives from Natick and various other places.

DISCUSSION.

Dr. George B. Shattuck, in opening the discussion of the subject, said that he only consented to do so in the hope that others better acquainted with it, and who had personally inspected the sewage farms at Gennevilliers, at Berlin, Dantzic, and in England, might be induced to give their views. As the Society was fortunate enough to enjoy the presence of past and present members of the State and City Boards of Health, as well as of several able and distinguished engineers, he felt sure justice would be done the subject, than which none more important awaits regulation in the older Eastern States, and he would confine himself to a brief statement of the general methods of the disposal of sewage as at present understood and practiced. These may be included under three heads: (1) immediate discharge into some neighboring body of water, stream, lake, or ocean; (2) chemical precipitation of solid constituents: (3) discharge upon land to be disposed of by downward filtration through the soil or by broad irrigation for purposes of agriculture and fertilization.

The method of chemical precipitation might, as Dr. Barnes's interesting paper plainly showed, be left out of consideration as unsolved. Of the other two methods the first was comparatively simple, satisfactory, and inexpensive, where there was in the immediate neighborhood a large body of deep water moved by tides or currents sufficiently active to carry off or oxygenize the sewage without its becoming a nuisance to other places in the process. Boston, the speaker thought, was so situated.

In discussing the disposal of sewage by the aid of the soil Dr. Shattuck said the systems of downward filtration for epuration, or of broad irrigation for agricultural purposes, ought to be carefully distinguished from each other, it being possible, as a rule, to use a

larger and less variable amount of fluid in the former than in the latter method. The successful application of either of these systems must be governed by many variable factors, so that no general laws had been or probably would be arrived at. Each place must work out its own problem and its own sewage salvation. In discussing sewage-farming one must bear in mind the character of the soil, whether sand, clay, or loam; the character of the climate, whether moist or dry, hot or cold, or variable; the kind of crop for which there is a market, whether coarse grass or garden vegetables; and last, but not least, the composition of the sewage itself, the proportion of solid constituents to liquid as determined by rainfall or by *per capita* amount of water used or quantity of solids admitted to the sewers.

It should not be forgotten that the present sewage irrigation at Gennevilliers was voluntary with the farmers, who used it or not as they chose, and the calculation of 2000 hectares (about 5000 acres) with which to handle the whole of the 110,000,000 cubic metres of annual sewage of the city of Paris, the speaker thought, must be based rather upon the system of downward filtration than upon that of broad irrigation for agriculture.[1] Dr. Shattuck was not aware of any application of sewage-farming upon a large scale which had proved actually profitable. It would generally, he thought, prove a question of comparative cost.

Mr. E. W. Bowditch, sanitary engineer, stated that the assertion which was contained in the paper that the water supply of Chicago is contaminated with sewage from the city is not probably correct. A year ago there was no positive proof of the truth of this statement, although the time will come when this will be true unless the crib for the supply is carried farther out into the lake. In regard to the frequency of

[1] At least it allowed about fifteen times as much sewage to the acre as was thought desirable for agricultural purposes by the commission appointed to consider the best disposition of the sewage of the city of Worcester.

the cleansing of the cess-pools so often attached to dwellings in cities, an incident occurred a few days ago which illustrated the average degree of sanitary knowledge possessed by the average citizen. A gentleman in speaking of cess-pools stated that one great objection to their use consisted in the necessity for their periodical emptying and cleansing. During further conversation the fact was disclosed that the cess-pool on the premises occupied by the gentleman had not been emptied in eight years.

The accessible reports on the disposal of sewage by the aid of irrigation and agriculture do not agree, thus making it very difficult to arrive at any definite opinion upon the merits of any special plan. Probably, too, each particular locality and each individual system presents different conditions, and has its own particular drawbacks.

At Pullman, Ill., which has been considered the model of disposal of sewage by and of agriculture, it is said that this plan has been abandoned, and that the sewage is now poured into Lake Michigan.

As far as Massachusetts is concerned there can be but little question that the rigorous climate of our winters would seriously interfere with the filtration of sewage in the colder months, and there is lack of enthusiasm among the farmers to test the efficacy of the plan.

The sewage of the Mystic Valley corresponds exactly to what it is supposed to be. It is possible and quite probable that a series of filters would be useful in clarifying the foul water of this sewer, though it would not purify it. Some time ago a barrel of Mystic sewage was sent to New York to be used as a test for a process for purifying foul water. Upon return of the purified product it was found to be free from any offensive quality. At the same time a sample of water which receives the drainage of sixty tanneries was also forwarded, and this, although originally very much polluted, was returned free from any offense, and has remained sweet and clean for a period of many months.

The general question of sewerage is daily assuming a more prominent position among the economical topics of our towns and cities. Of 346 towns in the Commonwealth eighty-four have already introduced works for public water service. Of these eighty-four towns twenty-six have also sewerage systems, while the other fifty-eight have water brought to them, but no means of its removal. These towns will be obliged to adopt some means of purifying or disposing of sewage in order to obviate nuisances which must otherwise inevitably arise. It is not easy to see how towns more than ten miles from Boston could possibly unite on or derive benefit from a metropolitan sewer. The cost would be too high, and the towns could not possibly afford it. From experiments which have been made with the object of forming an opinion on this subject, and which have been quite extensive, it would seem that the most practical solution of the sewage problem might be found in some process of purification.

Dr. H. P. Walcott, of the Massachusetts State Board of Health, in response to a call from the chair, spoke as follows: The statements of previous speakers render any general discussion of the subject of irrigation unnecessary, and I shall, therefore, confine myself to the sewage farms of Berlin, having had very favorable opportunities for studying them. To me they represent the best experiment thus far made in sewage disposal by way of irrigation, far more complete than anything of the sort in England or France.

Two farms, Falkenberg on the northeast, and Osdorf at the south, are the localities at present made use of. The acreage has been steadily increasing, and now (1884) appears to be between nine and ten thousand acres, of course not all prepared, perhaps not twenty per cent.; Falkenberg so incomplete as to be in an unsatisfactory condition; Osdorf, in the finished parts, eminently satisfactory: no smells except localized ones about outlets of sewer: soil under-drained; effluent from subsoil drains, clear, free from smell or taste, as

good as the average drinking water of Berlin. In the earlier days of the farm the principal crops, rye grass and cabbage, were readily sold at remunerative prices; the markets are, however, now overstocked in these articles, even though large quantities have been sold in markets comparatively distant from Berlin.

The sewage question in Berlin has, however, never depended upon financial considerations; irrigation (from the height of water level in the soil and very slight fall in many miles below Berlin of the river Spree) was a necessity, something to be had at any cost. Enormous as this cost has been the money is shown to have been well spent by the improved sanitary condition of the city, therefore any money return is so much gained. There is one arrangement at the Berlin fields open to serious criticism, the so-called winter basins, into which sewage is run during seasons of the year when crops are not in growth. These are many acres in extent, act simply as filters, receive sewage in very large quantities, which occasions an offensive deposit, to be plowed into the soil in the spring, the ground then planted with grain, and receives no more sewage except in case of drought. These basins are for a time quite offensive, and would not, I think, be tolerated in this country. Gennevilliers lacks one of the great elements of success at Berlin, the strict control by competent authority. At Gennevilliers the farmer takes the sewage or not as seems best to him. Upon one visit to Gennevilliers no sewage at all was being disposed of by irrigation; all was going to the river; this was naturally during damp, overcast weather.

No experiments of any value have been made in this country. Colonel Waring's system at Sherborn was very expensive in first outlay; does not furnish a satisfactory effluent. Broad irrigation at Insane Hospital at Worcester is a complete success, but under conditions which it would not be possible to imitate in many towns. It is to be hoped that the preparations for a system of irrigation for sewage of prison at Concord

may be carried out, and give an opportunity for careful determination of questions as to evaporation, etc., which have never been studied in this country so far as irrigation fields are concerned.

Dr. C. F. Folsom said that there is no longer any doubt of the facts that sewage can be purified by irrigation, that the crops raised are suitable for food, and that sewage farms can be managed without creating a nuisance. This is all very expensive, however, and in no case has a sewage farm been carried on for any length of time, except on the scale of a few acres, in such a way as to satisfy the sanitary requirements of the case without the incurring of very considerable pecuniary loss. In Paris, Dantzic, and Berlin the loss is very considerable, but these cities are so situated that they must have sewage irrigation if they have sewerage, and the outlay on the sewers is reckoned with the deficit from the sewage farms as the cost of cleaning the cities and improving the public health. The great rise in the value of the land where sewage is used in irrigation near Paris is due to the fact that it is near an immense and rapidly growing city, and applies to land where sewage is not used as well as to the irrigated land. The soil, too, is of such a character that the farmers use wind-mills and ordinary irrigation for garden crops, and in some cases prefer it as being less offensive than the sewage.

There is no land in Eastern Massachusetts quite suited for sewage irrigation on a large scale, but near Worcester and Natick there is land which can be made available for that purpose just as soon as the authorities decide that the nuisance of the present methods of sewage disposal is great enough to justify the trouble and expense. If the sewage of Boston were used in irrigation there would be an annual loss to the city from that source alone of a sum somewhere between twenty thousand and fifty thousand dollars. The pecuniary value of the sewage of Boston can be estimated roughly by remembering that its strength is

represented by the daily excrement of one person in three barrels of water, forming a fertilizer which no one would think worth much for daily use in his garden.

Alexis H. French, Esq., engineer for the town of Brookline, said: "In the present state of chemical and agricultural science an engineer would not be justified in departing very far from the practice that has heretofore been followed in the disposal of the sewage of the favorably situated cities and towns, in the simplest way possible, provided that this method did not menace the public health. Pending the discussion and experiments on the subject which, it is to be hoped, will be continued until some satisfactory solution will be obtained, the engineer has to face the question in the light of the existing information, and do the best for his clients that the circumstances will allow.

"In relation to the present systems of sewers, it may be said in their favor that while it is more than probable that eventually some method of sewage disposal will be discovered which shall be unobjectionable in a sanitary point of view, if not in an economical one, these same systems will continue to collect the sewage, and will not, therefore, prove to be the vast financial loss which might seem to be the case from such a change in plan.

"One of the greatest obstacles to sewage irrigation in New England is the peculiar topography, this method of disposal, as I understand it, requiring comparatively level land, which, to take the drainage of our larger cities, must be several square miles in extent. It would, perhaps, be applicable to the smaller cities and towns, where the 'separate system of sewerage,' as it is called, is in use, and to those western cities which have near at hand large areas of prairie land favorably situated, both for receiving the sewage and for the subsoil drainage which this system necessitates."

Dr. John G. Blake said that when we succeed in obtaining a law which shall compel towns to take prop-

er care of their sewer products, we shall have made a great advance in the solution of the question of irrigation and agriculture. There are certain weighty objections to be first overcome. It is well known that the population of Eastern Massachusetts is to a very large extent composed of the classes of artisans and mechanics, or manufacturers, and that agriculture as a commercial or economical pursuit is not cultivated to any considerable extent. This interposes a certain amount of indifference, and even opposition, to the introduction of irrigation and agriculture as hygienic measures.

There is reason to hope that within a short time the town of Natick, which is at present the gravest offender in the pollution of the Boston water supply, will be forced to purify its sewage products, and to render its waste water harmless before it is poured into the reservoir from which the citizens of Boston are now drinking.

In relation to the sewage problem in the Mystic Valley the condition of things there is not yet quite satisfactory. The water as it is now discharged is far from pure. The owner of a new filter, however, agrees to supply a series of filters which shall remove all suspended matter in the water, and we propose to dispose of the rest by irrigation. The city owns five acres of land which can be utilized for that purpose, and it is probable that the experiment will be tried, and, if found successful, it may be extended. Dr. Blake then moved that a special meeting be provided for the further consideration of the present subject, which was carried, and the Secretary was directed to arrange for such a meeting in the near future.

Adjourned at 10.15 P. M.

ADJOURNED SPECIAL MEETING.

MAY 21, 1884.

The CHAIRMAN introduced the subject for this meeting, which was the continuation of the discussion upon the

EPURATION OF SEWAGE BY IRRIGATION AND AGRICULTURE,

the first discussion of which took place April 30th, and is reported in the JOURNAL, vol. cx., page 609.

MR. ELIOT C. CLARKE was first called on, and spoke as follows: "Much has been said lately of the successful disposal of sewage at Pullman, Ill., by land irrigation. It affords almost the only instance in which it is claimed that pecuniary profit has attended such a method of disposal. I have recently visited this sewage farm, and the result of my observations there may be interesting to the Society.

"Land irrigation was adopted at Pullman, not with the hope of profit, but from necessity, there being no other practicable means of getting rid of the sewage except at enormous expense. House sewage only, of which there is a daily supply of about 200,000 gallons, is disposed of by irrigation. Rain and water used for mechanical purposes are not mixed with the sewage proper, but are discharged into Calumet Lake.

"The whole sewage farm consists of 1500 acres of flat prairie, situated within two miles, or less, of the town. Of this area, however, only 150 acres were used last year in purifying and utilizing the sewage, the remainder being held for future use, or cultivated without the application of sewage. The soil is a rich loam underlaid by sand. The portion to which sewage is applied is all underdrained by pipes about six feet below the surface. About ten acres are prepared as filter beds, being more carefully underdrained than the rest, and this tract disposes, by filtration, of the sewage at such times as the crops need none or would be injured by it.

"The crops to which sewage is furnished are, chiefly, celery, cauliflower, cabbage, and other kinds of garden produce which flourish with a copious supply of water. The sewage is only applied to them at such times and in such quantities as is beneficial, principally in the morning and evening, during dry weather. Some crops, as potatoes, never receive any sewage, since it is found to injure them. The superintendent, Mr. Martin, thinks he gets earlier and better vegetables than he would from land that was not irrigated. He also believes (without special opportunities for comparison) that the crops do better with sewage than they would if simply irrigated with pure water, that is, that the sewage acts somewhat as a manure. It is evident, however, that it does not act as other manures do, because he finds that it injures the land to apply sewage to it longer than for one season. After one season's application the sewage should be omitted for a year and the land, instead, enriched with barn-yard manure.

"The profit last year from sale of crops grown on that portion of the farm irrigated with sewage was about $5000. The superintendent thinks that, had it not been for early frosts, the profit would have been $7000. In calculating this gain, however, no charge was made for rent of the land or for interest on the cost of draining and otherwise preparing it, or for the machinery and other plant necessary to raise and convey the sewage to the farm, or for fuel and attendance on the pumping engines. These items would have largely exceeded the calculated profit, so that had it been possible to have discharged the sewage by gravity into some neighboring body of water it would have been much cheaper to do so.

"Under the circumstances the result is very satisfactory. The town gets rid of its sewage without creating any nuisance. No trouble has been experienced in winter. During very cold weather an inch or so of ice forms on the surface of the filter beds, but the ground beneath remains open and the sewage soaks away. Thus

the primary object of the farm, which is to get rid of the sewage at all times, is satisfactorily accomplished, and, in addition, the land is cultivated, and the value of the crops produced exceeds the cost of cultivation.

"While the result at Pullman is encouraging for those towns which are compelled to purify their sewage on land there is nothing in it to commend sewage farming to towns which can discharge into water without doing any harm thereby. The conditions for sewage farming would rarely be so favorable as they are at Pullman. At that place a comparatively small amount of sewage is to be disposed of, and close at hand is available an abundance of cheap but rich farming land, perfectly flat, and with soil especially adapted to the purpose.

"In Boston the territory south of Charles River furnishes, in dry weather, one hundred times as much sewage as Pullman. If the same ratio between acreage and sewage were preserved, Boston would need a farm of 15,000 acres, an area as large as the city proper, South Boston, Dorchester, Roxbury, Brookline, and Brighton. It is needless to say that no such area suitable for the purpose can be found within accessible distance.

"The sewage of Pullman is about three times as dilute as Boston sewage, but otherwise appears to be the same material. It is allowed to flow on to the land each morning and evening unless rains occur, when it is not used so frequently.

"The effluent water is clear and free from smell or taste, and fish are found at the outlet of the filter beds, which is considered possible only in pure water. At the opening of the sewers there is a perceptible odor, but it is the smell of fresh sewage, and not that of decay or decomposition. The superintendent of the farm resides at a short distance from the filter beds, and suffers no inconvenience from their proximity to his dwelling, and his family have never been afflicted with any disorder attributable to that cause. The centre of the farm is between one and two miles from the centre of the city."

Dr. Faxon stated that he had listened with much satisfaction to the discussion, but that one element existed in American sewage which was not found in that of any European system. The sewage of every American city is loaded with tons of grease, which materially interferes with its utilization in the same manner as is followed in other countries. The greasy contamination forms a solid crust in the upper layers of the soil, which the roots of plants cannot penetrate. The Pullman farm is far from representing the actual results of such a system in its more extended adoption. The sewage from Boston is at present discharged into tidewater, but the nuisance of sewage pollution is not removed. A certain portion of Boston sewage comes to the shores of Quincy Bay, and is already creating a nuisance along the beach in that vicinity. From the windows of the Sailors' Home at that place can be seen a layer of sewage many acres in extent upon the surface of the water between that point and the neighboring islands. As summer approaches the sludge becomes more abundant, and is thrown up on the shore, where its stench becomes intolerable. Some other method than the present must ultimately be adopted for the disposal of the sewage of Boston.

If an engineer were requested to designate a perfect system of sewerage it is quite impossible to say what method would be recommended, but at present, everything taken into consideration, filtration seems to be the most available method known.

In reply to Dr. Faxon Mr. Clarke said: "This is the first intimation I have had that the Sewage Works at Moon Island create any nuisance or are likely to. Those who live on the island experience no discomfort. I have seen some sludge about the outlet, and there are places on the Works where one can get the odor of sewage. That was to be expected. The sewage which is discharged at Moon Island formerly emptied at fifty outlets in Boston, and made fifty nuisances close to residences, places of business, hospitals, bathhouses, etc. It has not been changed to cologne water

by being diverted to Moon Island. But I do not believe that any nuisance will be created there which can possibly affect any one not living on the island.

"Although a little of the sewage may deposit near the outlet, almost all of it goes out of the harbor. It follows an unvarying course between Long and Rainsford Islands, and none of it ever turns into Quincy Bay. Its outward course can be distinctly traced for about a mile, but at a little greater distance from the outlet the dilution with salt water is so great that all trace of the sewage is lost."

Dr. Marcy inquired of Dr. Faxon the reason why he believed the fatty matter of sewage caused the soil to mass together and thus, as stated, prevent penetration by the rootlets of plants. Dr. Marcy questioned if this could really be true, since the fatty materials of sewage are chiefly animal, and it is well known that these rapidly and easily undergo fermentation and decomposition, setting free the fatty acids at ordinary temperatures. Thus these compounds are taken to pieces by the action of the bacteria and fitted to serve as plant food. Dr. Marcy inquired as to the filtrative power of the soils as shown in the experiments of Dr. Faxon and at the Woman's Prison, saying we must bear in mind that for about six months of the year in our latitude there is very little vegetation, and provision must be made for winter sewage. Contrary to the usual belief, sand makes a most unreliable filter.

Mr. Edward S. Philbrick, C. E., spoke as follows: "The subject under discussion is a very broad one, and I shall therefore limit myself to the question of applying the sewage of *Boston* to irrigate the soil. While not wishing to be understood as opposing the system of irrigation by sewage in general, and while recognizing the importance of making strenuous efforts to prevent the pollution of water supply by a reckless discharge of sewage into natural water courses,[1] I will

[1] It seems to me that Dr. Barnes has informed himself chiefly by *reading*, and that his reading has embraced only one side of a question which has been attended with a very warm *partisan* discussion

refer to some of the obstacles which tend to render sewage irrigation a difficult plan for this city.

"The money value of the solid and dissolved ingredients of sewage has been urged by many persons who have investigated the subject. Many skilled investigators have devoted their attention to this question, particularly in Europe, within the past ten years, and we have much information from that source as well as from the experiments made by European towns in the disposal of their sewage by irrigation.

"But the money value of the ingredients of sewage is by no means the only question of importance in the consideration of its disposal. It has often been found in developing mines that the number of pounds of copper or silver in a ton of ore, as determined in the laboratory by assay, is but a poor guide in deciding upon the value of the ore or the mine. We must also know what it costs to stamp, wash, and smelt the ore and refine the metal that exists in that ore before its commercial value can be established. So in the disposal of sewage by irrigation it has often been found impossible to recoup the cost of the process by the product of the farm. The disposal of the sewage in some *innocent* way is necessary to the welfare of the community, so that for sanitary reasons such a course may often be the very best, though no source of profit, simply because it is the cheapest way of getting rid of a dangerous material; but it should not be regarded as likely to be *profitable* as a commercial undertaking, except under the most favorable circumstances.

"The difficulties met with are such as these: Plants that are useful as farming products do not tolerate a constant saturation of the soil they grow in. Therefore a sufficiently large area of soil must be treated to allow of applying the sewage on alternate fields, so that

in England lately. I hope its discussion here may be more deliberate and of a broader character. One thing is certain in my mind, namely, that it is a large question very largely, and that *patent* systems are no more likely to be widely applicable in our profession than in your own, and for similar reasons.

one may be receiving it while it is soaking away on the other. Even then we find that the plants which need a copious supply during a certain stage of their growth need much less at other stages when approaching maturity. We find, too, that the crops which are benefited by a large quantity of fluids in a dry month would be destroyed if an equal amount were put on the land in a rainy month. Now since the flow of sewage from any city is likely to be rather more copious in a rainy period than in a dry one, even though pains may be taken to exclude the rainfall from the sewers, the crops are often drowned with sewage at one time while getting barely enough to supply their wants at another. For this reason those sewage farms have been most successful where the farmer was not obliged to take the *whole flow*, but merely what he desired from time to time.[1]

"In order to make sewage irrigation successful the land must be located favorably, must not be too steep in its declivities, and must be had at low rates of cost, that is, consistent with prices paid for other farm lands. Such a surface is not easily found near Boston.

"However great the advantages of irrigation may be to certain crops, it is not so applicable to hoed crops as to the grasses, for the reason that irrigation puddles the surface, which unless very sandy cakes and hardens when drying, requiring frequent hoeing to pulverize the soil. Therefore it has been found that Italian rye grass is the best crop for sewage irrigation. But this is a crop which is poorly adapted to our climate and is of little value except for soiling cattle. Moreover we have in this climate at least six months of every year when no such crop can be grown, while the flow of sewage is continuous during the year."

Mr. Desmond FitzGerald, C. E., said that the improved system of sewerage for the city of Boston

[1] The success of the Gennevilliers sewage farms, as I am informed, is attributable to this fact, that the delivery of sewage to the farmer was at his option and not obligatory. Such a system can never be a reliable source of relief to a town so long as any considerable portion of its sewage flow is liable to be left undisposed of in a wet day.

was so designed that if it should ever be found desirable to utilize the sewage, it could be done, but that in the present experience of dealing with as large a quantity of refuse water as that now supplied by Boston, and considering its highly diluted state, it would be a great waste of money to attempt any scheme of utilization. In regard to inland towns situated on the borders of water-sheds used for sources of water supply, the case was, however, far different. Here very small amounts of sewage had to be dealt with, and there was little doubt in his mind that some scheme either of filtration or irrigation could be successfully applied. The speaker did not intend to use the word success in a pecuniary but in a sanitary sense.

Mr. FitzGerald proceeded to describe the actual condition at the present time of the several sources of supply of the city of Boston, and of his attempts to preserve the purity of the same. He showed that the time had now arrived when some principle of action must be assumed. Either the brooks must be given up to the towns for common sewers or the towns must be made to take care of their sewerage in a proper manner.

The speaker went on to show that the brooks are now used for drainage only by those people who happen to own land on the margins, while the neighbors immediately adjoining have to provide for their sewage by emptying their cesspools, etc., and the hardship and injustice of this is not denied. Mr. FitzGerald described the works at Sherborne, which are sub-surface irrigation combined with intermittent downward filtration. He said the works had been very much misrepresented, and that while no filtration system removed the chlorine, yet the effluent water was clear and inoffensive to the eye or smell, and practically the filthy condition of the sewage is very materially improved. The speaker agreed with the statements made by Mr. Ernest W. Bowditch at the last meeting, that no cast-iron rule could be made to suit all cases, but that as

the circumstances and situation of every town were different, so a study would have to be made of each case, and that system adopted which best suited its peculiarities.

Dr. John G. Blake remarked that, looking at the subject from the health stand-point alone, it was becoming every day more necessary that some solution of the sewage question must be attempted if the health of communities as affected by their water supply was to be considered. What is wanted to hasten the solution of the subject is a law compelling towns bordering on rivers, ponds, and lakes to make some other disposition of their drainage than to allow it to run into these as receptacles. Up to the present time it has been impossible to convict offenders, but during the past winter a law, more stringent in character and free from the defects in previously existing laws, was passed, and under it, action to punish offenders will soon be commenced and pushed vigorously. From what had been said on the subject Dr. Blake is inclined to think that irrigation might prove itself very well adapted for small country communities without any regular system of drainage. The question of profit might well be left for later discussion, and the only point deserving consideration was the disposal of their sewage at the least expense and in such manner as to prevent its becoming a source of injury to themselves and others. Inasmuch as eighty cities and towns are moving to supply themselves with water, the importance of this subject had become very much magnified, and action looking to a remedy must soon be taken.

Dr. Barnes, in closing, said: If the theories advanced in opposition to the employment of irrigation and agriculture for the epuration of sewage had not been used in Europe, and finally overcome by actual experience, one would hardly feel like continuing to advocate this system for Massachusetts. My enthusiasm, however, does not carry me so far as to suggest

even a possibility of the abandonment of Boston's system of intercepting sewerage, notwithstanding the probability of its polluting the lower harbor and producing an unsanitary condition similar to that of the upper harbor, and an annoyance to the people living on the south shore, for before this condition is reached it may fairly be anticipated that irrigation and agriculture will have proved here, as in Europe, an economical and practical method of epuration. The sewer can then be extended to the main land and discharged on the soil. "It will not be possible, however, to connect any territory adjacent to Boston with this system without constructing an additional tunnel under Dorchester Bay." This is the language of one of Boston's officials a few weeks since before a committee of the Legislature. Filtration has, in numerous instances in Europe, accomplished complete clarification of sewage, and yet the analyses show the effluent water to contain from one half to six sevenths of the original amount of polluting matter. Colonel Waring's system of filtration at the Women's Prison accomplishes all that is possible, and yet the analyses show the result to be far from satisfactory. Pasteur and Shloesing, with others, sign a report to the Parisian government in which is stated, "The system of epuration by soil is the only one yet demonstrated to be a success. The discharge should be intermittent, and with methodical rotation, and the doses should be determined by analyses of the effluent water."[1]

At Dantzic is encountered a mean winter temperature about that of our own. Irrigation is continued

[1] It would hardly seem necessary to affirm before a scientific body of men that clarification is not purification, or that no system of epuration of sewage is satisfactory which by analysis shows quite as much pollution in the effluent as in the influent water. (See analysis of the sewage of the Women's Prison.) As to the average rain-fall of Great Britain the figures quoted were obtained in the office of the United States Signal Service and from Professor Niles. But as it is more a question of average humidity which determines the evaporating power, a few inches more or less of rain-fall per year is of little consequence.

throughout the year with quite as much success in epuration in winter as in summer, and at all times without offense.

The "winter basins" at Breslau are not a part of the system advocated, as they involve the stagnation of sewage.

"The rosy coloring" of the Gennevilliers farms was not my own painting, but the translation of a report by a commission appointed by the city government of Paris, to whom, it seems to me, ought to be accorded the credit of knowing the facts, particularly as the report was unanimously signed. These gentlemen say "the increase in valuation and population at Gennevilliers is due to farmers coming from other parts of France to share in the general prosperity." Durand-Claye says "the population of Gennevilliers has increased thirty-four per cent. in five years by the arrival of numerous cultivators." M. Joly says of the Gennevilliers farms: "The question, scientific and practical, is absolutely solved." And Dr. Loiseau, at the Geneva Congress, in 1882, said "the benefits derived from these farms are indisputable from every point of view."

I was amazed at the statement that no person knew the cost of the Gennevilliers farms, as I have in my library an official document of Paris pretending to give every item of expense from the first experiment at Clichy, in 1867 and 1868, down to 1882, including lawsuits and large indemnities paid for an unfortunate experiment.

In regard to the city of Pullman making arrangements to pump the sewage into the lake I have the following letter from the superintendent of the farm: —

RIVERDALE, COOK COUNTY, ILL., *May* 9, 1884.

DEAR SIR, — If any such arrangements as you speak of in yours of 6th inst are being made I have no knowledge of the fact. The sewage is thoroughly purified by filtration, creating neither offensive odor nor nuisance of any kind.

The farm, last year, paid over six per cent. profit on the money invested ($80,000), and we hope this year to do even

better. Consequently there exists no necessity for any such change as you speak of.

Very respectfully, E. T. MARTIN, *Superintendent.*

HENRY J. BARNES, M. D., BOSTON, MASS.

It should be mentioned here that downward intermittent filtration is a valuable auxiliary to sewage farming. I. Bailey Denton has written considerable upon this branch of the subject. I regret not knowing the history of the Pullman farm, as I should like to pay a proper tribute to the pioneer of this system in America.

The unprofitable results of sewage farming have been dwelt on by most of the opponents of the system, forgetting that it is a question of sanitation and not of making money, and if raising vegetables contributes in any degree to lessening expenses it takes precedence in a financial point of view of all others, as they make no return for the original outlay except the almost universal offense they create.

It has been a long and costly struggle to demonstrate the fact that sewage can be epurated by irrigation and agriculture. Every conceivable danger has been predicted. And many are the unfortunate and disastrous experiments which can be cited, swelling the cost above the possibility of many of the farms earning interest on the plant. To obtain an act of Parliament authorizing the establishment of a sewage farm often requires the expenditure of £10,000. Litigation and land damages, another large amount, for land is very dear in England. The heavy clay soil demands a large expenditure for drainage. But notwithstanding these obstacles the number of farms has rapidly increased, until now there are at least two hundred.

The Royal Commissions recommend the enactment of a general law authorizing farms of this character.

In 1876 Messrs. Chesbrough, Lane, and Dr. Folsom, Commissioners reporting on the sewerage of Boston, say "the Edinburgh farms are profitable." One of the commissions appointed by the Parisian government declare

the sewage farms at Gennevilliers profitable, and use this as one of the arguments in support of their recommendation to the city to purchase the State lands in the forest of St. Germain. The owner of the farm at Leamington (which, by the way, has not been leveled) as well as the superintendent of the farm, claim a good profit after paying the city $2250 per year for delivering 1,000,000 gallons each day at the highest point of the farm.

Mr. Aird could not have lost a large amount of money in his contract to take the sewage of Dantzic, for some years later he made a similar contract with the city of Breslau. But it ought not to be required of the friends of this system to show profit until at least one system is devised capable of competition with this in producing satisfactory epuration.

The enormous dilution of sewage in this country is mentioned as an objection. By analyses the amount of organic matter in the sewage of American and European cities varies but a trifle. Boston consumes more water per capita than Paris. But the latter city dilutes her sewage equal to that of our own by a lavish use of water in washing the streets each morning. And the estimate of three barrels of water to the discharge of one individual here does not include the organic matter constantly discharged from sink drains or the street washings. Durand-Claye, the celebrated French engineer, to whom the world owes a debt of gratitude for demonstrating the possibility of epuration by this method, says, "It is desirable and necessary that there should be a great dilution by water in order to insure rapid transit."[1]

The soil does not clog where systematic irrigation is practiced. The thin skin of impervious deposit, when dried, shrinks, cracks, and breaks up, the organic matter decays, and the soil is more pervious than where irrigation is not employed. Reservoirs of deposit are

[1] Babut du Marès quotes Dr. Carpenter as saying "the more dilute the better."

used to eliminate the coarse particles, as their decay on the surface would cause an offensive odor.

It is highly probable that the failure mentioned as resulting from an impervious deposit where "sewage was pumped on a garden," was due to puddling. And that it is an unnecessary accompaniment to irrigation is proved by the employment of this system at Buntzlau on fifteen hectares for over two and a half centuries, and at Edinburgh for over two centuries, without diminishing the permeability of the soil.

As to the impossibility of obtaining suitable soil of sufficient area in Massachusetts for the general employment of this system, the success which has attended the efforts of the English in finding it in their thickly populated island is an answer. Our forests could be utilized with little expense, and next to Italian rye grass the trees would prove the best absorbers of filth. A few acres of willows at Windsor take care of the sewage of twelve thousand people.

I recall but one other objection, the comparatively large rain-fall here, forty to fifty inches per year. At Gennevilliers 312 inches of water is sent on the land each year, and this "without making it damp or marshy since the establishment of subsoil drainage." And I know of two farms in my native town, in Worcester County, where irrigation with brook water has been practiced with advantage. Our average rain-fall is a little larger than that of Great Britain, where it is from forty to forty-five inches per annum, but the yearly average humidity (between eighty and eighty-six) is nearer the point of saturation there than here, where it is about seventy. Dr. Frankland considers the vapor in the atmosphere of England as "reducing the temperature from fifteen to twenty-five degrees:" and Tyndall remarks that "the abundance of atmospheric vapor hinders the radiation of heat at night in England." The protracted droughts which are so common in this country are unknown in England, where vegetation never suffers for want of moisture. I am

indebted to Dr. Bullard for facts and figures on this branch of the question, which enable me to say with positiveness that the meteorological conditions of our climate, with the possible exception of winter temperature, are far superior to those of England for the employment of irrigation and agriculture.

To-day I only ask that before building a metropolitan sewer for the eastern part of the State to discharge in tide-water, and thus repeat the now demonstrated errors of London, Brighton, and Torquay, irrigation and agriculture may be tried, on a limited scale, by some one having faith in the success, as we might ultimately desire to reverse the current of the sewage of the metropolitan district.

A large proportion of our rural population have gardens attached to their houses. I would discourage the use of cess-pools and recommend the use of these lands for the disposal of sink water. I am informed that Dr. Jewett, of Northborough, has for many years employed this system, and I have practiced it myself for ten years with complete satisfaction.[1]

Victor Hugo, in Les Miserables, describing the sewerage of Paris more than twenty years ago, makes a vivid picture of our systems at the present time. He writes as follows: —

"*The Earth Impoverished by the Sea.* Paris throws twenty-five millions a year into the sea. And this without metaphor. How, and in what manner? Day and night. With what object? Without any object. With what thought? Without thinking. For what return? For nothing. By means of what organ? By means of its intestine. What is its intestine? Its sewer. . . . Science, after long experiment, now knows that the most fertilizing and the most effective of ma-

[1] In view of the well-known results of chemical analyses of sewage the question as to its fertilizing properties seems to be out of place. It is almost the only fertilizer the Chinese employ. "The Duke of Portland used nothing but sewage on his farm at Mansfield, and obtained a net return of about $125 per acre." (Babut du Maris.)

nures is that of man. The Chinese, we must say to our shame, knew it before us. No Chinese peasant, Eckeberg tells us, goes to the city without carrying back, at the two ends of his bamboo, two buckets full of what we call filth. Thanks to human fertilization, the earth in China is still as young as in the days of Abraham. Chinese wheat yields a hundred and twenty fold. There is no guano comparable in fertility to the detritus of a capital. A great city is the most powerful of stercoraries. To employ the city to enrich the plains would be a sure success. If our gold is filth, on the other hand our filth is gold. What is done with this filth, gold? It is swept into the abyss. We fit our convoys of ships, at great expense, to gather up at the south pole the droppings of petrels and penguins, and the incalculable elements of wealth which we have under our own hands we send to the sea. All the human and animal manure which the world loses, restored to the land instead of being thrown into the water, would suffice to nourish the world.

"These heaps of garbage at the corners of the stone blocks, these tumbrils of mire jolting through the streets at night, these horrid scavengers' carts, these fetid streams of subterranean slime which the pavement hides from you, do you know what all this is? It is the flowering meadow, it is the green grass. It is marjoram and thyme and sage, it is game, it is cattle, it is the satisfied low of huge oxen at evening, it is perfumed hay, it is golden corn, it is bread on your table, it is warm blood in your veins, it is health, it is joy, it is life. . . .

"Statistics show that France alone makes a liquidation of a hundred million every year into the Atlantic Ocean from the mouths of her rivers. . . . The cleverness of man is such that he prefers to throw this hundred million into the gutter. It is the very substance of the people which is carried away, here drop by drop, there in floods by the wretched vomiting of our sewers into the rivers, and the gigantic collection of our

rivers into the ocean. Each hiccough of our cloaca costs us a thousand francs. From this follows two results: The land impoverished and the water infected. Hunger rising from the furrow, and disease arising from the river. . . .

"A system of elementary drainage, as simple as the lungs of a man, and which is already in full operation in several villages in England, would suffice to bring into our cities the pure water of the fields, and send back into our fields the rich water of the cities, and this easy see-saw, the simplest in the world, would retain in our possession the hundred million thrown away.

"The present system does harm in endeavoring to do good. The intention is laudable, the result lamentable."

On motion of DR. HENRY I. BOWDITCH, it was

Voted, "That the thanks of this Society be tendered to the scientific gentlemen, not members of our body, who have contributed so much to our instruction and to the great interest of these meetings."

Adjourned at eleven o'clock.